

FCRPS overwintering distribution and fallback behavior by adult steelhead radio-tagged at Bonneville Dam in 2013

– Letter Report, 26 September 2014

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Summary

- 789 summer steelhead were radio-tagged at Bonneville Dam in 2013; the sample was weighted for later ‘B-group’ migrants to increase the number of fish with FCRPS overwintering behaviors
- minimum FCRPS overwintering estimates were 7.7% for steelhead tagged in June to early August and 27.4% for those tagged in late September to mid-October; estimates were higher (12.2% and 37.8%, respectively) when we excluded fish harvested in the main stem and those that were unaccounted for
- overwintering steelhead were distributed throughout the FCRPS, but the largest numbers were in the Little Goose and Lower Granite reservoirs; this distribution was due – in part – to the abundance of Clearwater River fish in the sample
- 95 steelhead fell back at lower Columbia and Snake dams 158 times between 1 November and 31 March; fallbacks were most frequent during this time at The Dalles and McNary dams
- forebays at The Dalles, John Day, and McNary dams were monitored with aerial antennas from early December through 1 April; estimated steelhead fallback routes were: powerhouses (46%), spillways (18%), ice / trash sluiceways (10%), adult ladders (6%), and unknown (20%)
- several steelhead that fell back at the forebay-monitored dams in the winter held in or near the forebays for days to weeks during periods of no spill
- more than half (56%) of pre-spawn steelhead that fell back from 1 November to 31 March were subsequently detected in potential spawning tributaries
- 194 fallback events were recorded for 59 likely post-spawn steelhead kelts in April and May, mostly at Lower Granite and Little Goose dams

Introduction

This is a brief summary of the behavior and distributions of radio-tagged adult steelhead that overwintered in the FCRPS in 2013-2014. In previous radiotelemetry studies, approximately ~12% (*annual range* = 7-20%) of the summer steelhead that passed Bonneville Dam and subsequently reached spawning tributaries overwintered in the FCRPS (Keefer et al. 2008). Most overwintering steelhead slow or stop migration in response to falling water temperatures in late fall and then resume upstream movement in February-April as rivers warm or in response to maturation cues. Because the behavior is primarily temperature related, steelhead with later migration timing, including the two-ocean 'B-group' fish that originate in the Clearwater and Salmon Rivers (Brannon et al. 2004), are more likely to overwinter than early summer migrants. For example, more than 40% of the steelhead released in October in the previous six-year summary overwintered in the FCRPS (Keefer et al. 2008).

Some overwintering fish move upstream and downstream past dams, and the downstream 'fallback' behavior is a management concern given injury and mortality risks (Keefer et al. 2005; Wertheimer 2007). Risks appear to be elevated for pre- and post-spawn (i.e., kelt) steelhead in winter and spring when surface-flow routes are limited at the dams and fish are more likely to pass through turbines as a consequence (Colotelo et al. 2013; Khan et al. 2013; Rayamajhi et al. 2013).

The 2013 study objectives addresses in this letter report are:

- 1) estimating the percent of the radio-tagged steelhead that overwintered in the FCRPS;
- 2) summarizing the FCRPS distribution of overwintering steelhead;
- 3) evaluating when (all dams) and by what routes (The Dalles, John Day, McNary dams) overwintering steelhead fell back.

Steelhead collection and radio-tagging at Bonneville Dam

We collected and intragastrically radio-tagged adult summer steelhead at the Adult Fish Facility (AFF), located adjacent to the Washington-shore ladder. In contrast to previous radiotelemetry studies at Bonneville Dam, we did not tag steelhead in proportion to the 2013 run. There were two reasons for the disproportionate sampling: (1) later-timed migrants were targeted to increase the proportion of overwintering fish in the sample for distribution and fallback evaluations; and (2) an extended water temperature shutdown of the AFF prevented the scheduled tagging in most of August and early September, further skewing the sample towards late migrants.

On the days that steelhead were tagged, fish were selected in the order that they entered the AFF trap. We did not select for any particular size class or group but we did select *against* fish that had PIT tags from juvenile projects (i.e., 'known-origin' fish were excluded) due to concerns

about handling effects on research outcomes for other projects. Selection against known-origin fish meant that the samples were not fully representative of the 2013 steelhead run at large.

Fish receiving a radio transmitter (3-volt, MCFT2-3A; Lotek Wireless Inc.) were anesthetized in a ~18 mL/L solution of eugenol (AQUI-S-20E, Aquatactics). All were also tagged with a full duplex PIT-tag inserted to the abdominal cavity as a secondary tag that allowed identification of transmitter loss and provided additional detection data at sites not monitored with radio antennas. After recovery from anesthesia, radio-tagged steelhead were transported by truck in oxygenated river water and released ~ 8 km downstream from Bonneville Dam from sites on both sides of the Columbia River.

Radiotelemetry monitoring

We used an extensive array of fixed-site radio receivers with digital spectrum processors at dams, in reservoirs, and in major tributaries to monitor tagged steelhead (Table 1). Radio receivers with Yagi aerial antennas were used to monitor dam tailraces, reservoirs, and tributaries. At dams, most antennas were underwater coaxial cable antennas, though a few sites also had aerial Yagis, including forebay monitoring sites at The Dalles, John Day, and McNary dams that were installed in early December to monitor forebay residency and fallback by overwintering steelhead. Underwater antennas at dams were used to monitor fishway openings, collection channels, transition areas, ladders, ice and trash sluiceways (The Dalles and McNary only) and top-of-ladder exit areas. Fish detection efficiencies on these arrays have historically been >95% at most sites, and antenna redundancy in most fishways increased dam-wide detection efficiency to near 100% for upstream migrants. Downstream migrants (i.e., pre- or post-spawn steelhead that fell back) passed fewer antennas and therefore had lower detection efficiencies.

We supplemented the radiotelemetry histories using PIT detections inside dam fishways (Bonneville, The Dalles, McNary, Ice Harbor, Lower Granite, and upper Columbia River dams), in juvenile bypass systems, inside tributaries, and at fish collection facilities. The PIT detection data were downloaded from the Pacific States Marine Fisheries Commission PIT Tag Information System database (PTAGIS). PIT detections were also used to identify passage by steelhead that lost transmitters or that had transmitters that were not working. Both radio and PIT data were used to assess overwintering, pre-spawn distribution among tributaries, and to assign final detection locations.

Results: sample summary and upstream migration timing

We collected and radio-tagged 789 steelhead at Bonneville Dam in 2013, including an ‘early’ group of 169 fish and a ‘late’ group of 620 fish (Figure 1). The early group was 0.2% of the 70,431 steelhead counted at the dam during the 22 June to 3 August tagging interval (i.e., there were ~417 untagged steelhead for each radio-tagged steelhead). The late group was 3.4% of 18,110 steelhead counted at the dam from 22 September to 15 October (~29 untagged for each

tagged steelhead). The total sample of 789 was ~0.3% of the 226,464 steelhead counted during the full tagging period (22 June through 15 October; ~287 untagged for each tagged steelhead).

The sample weighting towards late migrants was evident in the timing distributions of radio-tagged fish as they passed upstream dams (examples in Figure 2). Majorities of the tagged fish passed after the peak steelhead migration dates at all lower Columbia and lower Snake River dams.

Results: final distribution of radio-tagged steelhead

Excluding post-spawn kelt movements, about 36% (282 of 789 released) of radio-tagged steelhead were last recorded in the main stem Columbia or Snake FCRPS (Table 2). Of these ‘main stem’ fish, 51 (6.5% of 789) were angler-reported as harvested in recreational or tribal fisheries in the transmitter reward program. Another 210 (26.6%) of the sample was last detected in a reservoir or at a dam in the Columbia River downstream from Priest Rapids Dam or in the Snake River downstream from the Clearwater River / Snake River confluence. This group had unknown fate (i.e., was ‘unaccounted for’). The 26.6% was somewhat higher than in previous steelhead radiotelemetry studies (unknown fate = 12-23%; Keefer et al. [2005]), in part because the angler return rate was lower in 2013-2014, but also perhaps because all known-origin fish were excluded. A portion of the unaccounted for steelhead was presumed harvested (with no transmitter returns); others were presumed mortalities or entered tributaries undetected. The remaining fish in the main stem group either had apparent lost transmitters based on PIT detections ($n = 12$) or were last detected upstream from Priest Rapids Dam where monitoring was limited to PIT antennas ($n = 8$).

Steelhead were last recorded in a variety of Columbia River tributaries ($n = 123$, 15.6% of 789 released) and to the Snake River ($n = 384$, 48.7%; Table 2). The most abundant group was in the Clearwater River ($n = 233$), followed by the Salmon River ($n = 69$). Another relatively abundant group was last detected at the radio antenna in the Snake River upstream from Lower Granite reservoir ($n = 58$), and many of these fish presumably overwintered in the Hells Canyon reach prior to dying, being harvested, or entering unmonitored tributaries in spring 2014. The large proportion of the sample in the Snake River basin was not surprising given the relative oversampling of late migrant steelhead at Bonneville Dam. The largest tributary groups outside the Snake River basin were last detected in the John Day ($n = 41$) and Deschutes ($n = 33$) rivers.

Results: overwintering estimates

Determining whether steelhead overwintered in the FCRPS is a somewhat subjective task because the behavior varies among fish and defining “winter” is somewhat arbitrary. We followed the criteria in Keefer et al. (2008), where overwintering was assigned to: (1) steelhead that moved upstream past at least one FCRPS dam on or after 1 January (based on radio or PIT detections); and (2) steelhead that first exited a FCRPS reservoir into a presumed spawning tributary after 1 January.

We estimated overwintering percentages in two ways (Table 5). The first was the number of overwintering steelhead divided by the number radio-tagged and released. This was likely an underestimate of the behavior because some fish (i.e., those that were harvested) never had the opportunity to overwinter, but does represent an estimate of the proportion passing Bonneville Dam that are expected to overwinter. The second estimate excluded *a priori* the steelhead that were reported harvested in the FCRPS in the reward program and those that were ‘unaccounted for’ in the FCRPS. This modestly reduced the number of overwintering fish in the numerator but substantially reduced the number in the denominator and consequently likely produced modest overestimates of overwintering percentage. The second estimate is our best estimate of the probability of an individual overwintering given that it survived to reach a spawning tributary. In combination, the two methods likely bound the true overwintering percentage.

In total, we estimated that 173 steelhead retained radio transmitters and at least partially overwintered in the FCRPS; another 10 fish likely overwintered but lost or had non-functioning transmitters. Estimated overwintering percentages were 7.7% for the early release group and 27.4% for the late release group with all fish included (Table 5). The probability of overwintering was strongly positively associated with release date (Figure 3; logistic regression $\chi^2 = 30.3$, $P < 0.001$). When FCRPS harvested and unaccounted for groups were excluded, overwintering estimates were 12.2% (early) and 37.8% (late). The release date effect was similar in a logistic model ($\chi^2 = 24.7$, $P < 0.001$). The overwintering estimates and seasonal effects were broadly similar to those reported in the multi-year summaries in Keefer et al. (2008).

Results: overwintering locations

The FCRPS overwintering group was predominantly composed of Clearwater River steelhead (68%, 118 of 173), reflecting the late-timed sampling at Bonneville Dam. The next most abundant groups were John Day River ($n = 16$, 9%) and Snake River upstream from Lower Granite reservoir ($n = 15$, 9%). The remaining overwintering fish were last detected at a variety of sites, including the Salmon ($n = 4$), Grande Ronde (1), Imnaha (1), Tucannon (2), White Salmon (1), Hood (1), and Klickitat (1) rivers; 13 (8% of 173) were last recorded at main stem sites.

We used the radiotelemetry and PIT detections to estimate where overwintering steelhead were located on the first of each month from December through April (Figure 4). The largest numbers of fish were consistently in the Lower Granite reservoir reach (1 December, 1 January, and 1 February). Many fish were also in the Little Goose reservoir reach, followed by the reach upstream from McNary Dam. The overwintering concentration in the Little Goose and Lower Granite reservoirs reflects the preponderance of Clearwater River steelhead in the sample. The more representative sampling in Keefer et al. (2008) resulted in a broader spatial distribution of FCRPS overwintering, with proportionately more fish in the lower FCRPS. We note that Clearwater River steelhead in that study were also concentrated in the Lower Granite reservoir.

In each month, some overwintering fish exited the FCRPS into tributaries (Figure 4). The largest movement was in March, presumably in response to environmental cues (i.e., warming

and increased discharge) and reproductive cues. We note that some steelhead that eventually returned to Snake River sites partially overwintered in the Deschutes and John Day rivers, a ‘temporary straying’ behavior also consistent with results in previous years (Keefer et al. 2008; Keefer and Caudill 2014).

Results: fallback at dams

A total of 506 steelhead fallback events were identified at lower Columbia and lower Snake River dams (Figure 5). This was likely a minimum estimate because we think it was more likely for a steelhead to fall back without a radio or PIT detection than it was to mistakenly assign a fallback event to a fish that did not fall back. The total included 271 events (54% of 506) that were considered pre-spawn fallbacks, 194 (38%) that were considered post-spawn (i.e., kelt) fallbacks based on detection at appropriate times inside tributaries, and 41 (8%) that were uncertain with regards to steelhead reproductive status.

Fallbacks estimated to have occurred during primarily no-spill months included 8 in September, 65 in October, 52 in November, 24 in December, 9 in January, 17 in February, and 56 in March (Figure 5). These events were most frequent at The Dalles and McNary dams. Note that due to tagging restrictions, relatively few radio-tagged fish were migrating in early September, resulting in likely underestimation of fallback frequency for that month.

Additional radio antennas were installed in December at The Dalles, John Day, and McNary dams to help estimate winter-time fallback routes at these sites. During the extra monitoring period, 50 fallback events were recorded: 19 at The Dalles, 10 at John Day, and 21 were at McNary (Figure 6, Table 6). It was difficult to assign fallback routes using aerial radio antennas, particularly those that occur via deep water routes like the powerhouses. (Note: installation of underwater antennas along the face of the powerhouse was logistically impractical for this study.)

We were most confident assigning routes to 3 events (6% of 50) that moved down adult ladders and 5 (10%) that likely passed via ice and trash sluiceways at The Dalles and McNary dams (Table 6). Nine events (18%) were during the limited periods of spill (mostly in March and at McNary Dam) and route was assigned as ‘possible spillway’ for this group. Another 23 events (46%) occurred during no-spill conditions and were presumably via powerhouses or navigation locks. The remaining 10 events (20%) did not have any radiotelemetry records at the respective dams to help assign fallback route. We also note that juvenile bypass systems (JBS) were not operated at John Day or McNary dams during most of the overwintering period and no JBS detections of the overwintering fallback fish were recorded.

Detections on the forebay antennas at The Dalles, John Day, and McNary dams suggested that some overwintering fish spent extended time in the forebays prior to falling back, while others moved in and out of the range of forebay antennas prior to falling back (Figure 7). Several of the winter events at McNary Dam were associated with repeated forebay detections up until spill was initiated in March. It was not possible to differentiate steelhead movement upstream out of a forebay from movement into deeper water beyond the range of radio detection.

Many (50-71%) of the steelhead that fell back at the three dams during the forebay monitoring period eventually entered tributaries (Table 6). The ‘successful’ group that fell back at McNary Dam in winter primarily entered the John Day River, suggesting overshoot of the natal river. The successful fallback fish at The Dalles and John Day dams eventually entered a variety of tributaries, including the Hood, White Salmon, Deschutes, John Day, and Clearwater rivers (i.e., some were potential overshoot fallbacks, while others were followed by reascensions and successful upstream migrations).

Results: post-fallback survival

Across dams, non-kelt/pre-spawn fallback in any season was associated with survival to tributaries of ~50-58% (Table 7). This result was consistent with previous study results showing reduced escapement to tributaries by fallback fish (e.g., Keefer et al. 2005). Estimates of post-fallback survival varied considerably among dams, but comparisons were limited by within-season sample sizes. Across seasons, post-fallback survival to tributaries was lowest for steelhead that fell back at Lower Monumental (38%), Bonneville (39%), and The Dalles (54%) dams. We note that a small number of the fish that fell back and did not return to tributaries were reported as harvested, but most were unaccounted for. Final fate of these fish was unknown, but we presume that a mix of direct and indirect mortality due to fallback, lost transmitters, and unreported harvest.

Results: post-spawn (kelt) behavior

The 194 likely post-spawn fallback events we identified included 59 at lower Columbia River dams and 135 at Snake River dams. Collecting these data was not a planned study objective, but they provide relatively unique information, especially for the ‘B-group’ steelhead. Managers have been assessing how to improve kelt survival and iteroparity rates in the B-group segment of the population (e.g., Colotelo et al. 2012). Additional evaluation of the kelt behavior and downstream survival data we collected is underway.

Continued evaluation

These results are from year one of a two-year study. Radio tagging of the 2014 steelhead sample at Bonneville Dam is partially complete as of this writing. The preliminary results from year one presented here are broadly consistent with expectations regarding the abundance and FCRPS distribution and behavior of overwintering steelhead. The results indicate that thousands of steelhead overwintered in the FCRPS in 2013-2014 and that many of these fish fell back at one or more dams when surface-flow routes were limited.

The duration of temperature-related restrictions on fish handling at the AFF was considerably lower in 2014 than in 2013 and consequently the 2014 sample will include a more representative steelhead sample than in 2013. Some overweighting of late-run migrants is again planned in a continuing effort to have sufficient numbers of steelhead with FCRPS overwintering behaviors for use in fallback and survival analyses.

The primary consequences of the late season oversampling in both 2013 and 2014 are: (1) the sampled population is skewed towards B-group fish from the Snake River; (2) B-group steelhead are more likely to overwinter in the lower Snake River reservoirs than fish from the run at large, which are more broadly distributed; and (3) the distributions of pre- and post-spawn fallback events among dams are also likely skewed towards the Snake River projects. To address these issues, the final report will include FCRPS overwintering estimates and fallback metrics that are weighted by steelhead tagging rates at Bonneville Dam.

Confidently assigning fallback routes used by the overwintering steelhead was one of the more substantive challenges in the 2013-2014 study. Reduced demand for radio receivers in 2014-2015 should allow us to deploy additional antennas in forebays and some navigation locks. Data from these sites should reduce uncertainty with regards to route. We reiterate, however, that conclusive evidence of turbine passage is not possible with aerial monitoring only; estimates of steelhead use of turbine routes will necessarily be by subtraction.

Table 1. Radiotelemetry monitoring sites in the Columbia and Snake rivers in 2013-2014.

Site	Antenna type	# Receivers
Bonneville Dam Tailrace	Aerial	2
Bonneville Dam Fishways	Aerial	6
Bonneville Dam Fishways	Underwater	11
Bonneville Reservoir – Bridge of the Gods	Aerial	1
Bonneville Tributary – Wind River Mouth	Aerial	1
Bonneville Reservoir – Viento State Park	Aerial	1
Bonneville Reservoir – Cook-Underwood Rd	Aerial	1
Bonneville Tributary – Little White Salmon River Mouth	Aerial	1
Bonneville Tributary – White Salmon River	Aerial	2
Bonneville Tributary – Hood River Mouth	Aerial	1
Bonneville Reservoir – Chamberlain Lake Rest Area	Aerial	1
Bonneville Reservoir – Memaloose Rest Area State Park	Aerial	1
Bonneville Reservoir – Chamberlain Lake Rest Area	Aerial	1
Bonneville Tributary – Klickitat River Mouth	Aerial	1
The Dalles Dam Tailrace ¹	Aerial	2-4
The Dalles Dam Fishways	Underwater	8
The Dalles Ice and trash sluiceway ¹	Aerial	1
The Dalles Forebay ¹	Aerial	2
The Dalles Reservoir – Celilo Park	Aerial	1
The Dalles Reservoir – Wishram-Celilo	Aerial	1
The Dalles Tributary – Deschutes River Mouth	Aerial	1
The Dalles Tributary – Deschutes River Sherars Falls	Aerial	1
John Day Dam Tailrace ²	Aerial	2-5
John Day Dam Fishways	Underwater	6
John Day Forebay ²	Aerial	1
John Day Tributary – John Day River Mouth	Aerial	1
McNary Dam Tailrace ³	Aerial	2-6
McNary Dam Fishways	Underwater	6
McNary Ice and trash sluiceway ³	Underwater	1
McNary Forebay ³	Aerial	3
Priest Rapids Dam Fishways	Underwater	2
Ice Harbor Dam Tailrace	Aerial	1
Ice Harbor Dam Fishways	Underwater	6
Lower Monumental Dam Tailrace	Aerial	1
Lower Monumental Dam Fishways	Underwater	6
Lower Monumental Reservoir – Lyons Ferry Hatchery	Aerial	1
Lower Monumental Reservoir – Downstream of Tucannon River	Aerial	1
Lower Monumental Tributary – Tucannon River	Aerial	1
Little Goose Dam Tailrace	Aerial	2
Little Goose Dam Fishways	Underwater	6
Lower Granite Dam Tailrace	Aerial	2
Lower Granite Dam Fishways	Underwater	5
Lower Granite Tributary – Clearwater River near Potlatch Mill	Aerial	1
Lower Granite Tributary – Snake River upstream of 3 Mile Island	Aerial	1

¹⁻³ Overwintering monitoring sites installed 11 Dec (The Dalles), 16 Dec (John Day), 5 Dec (McNary) 2013

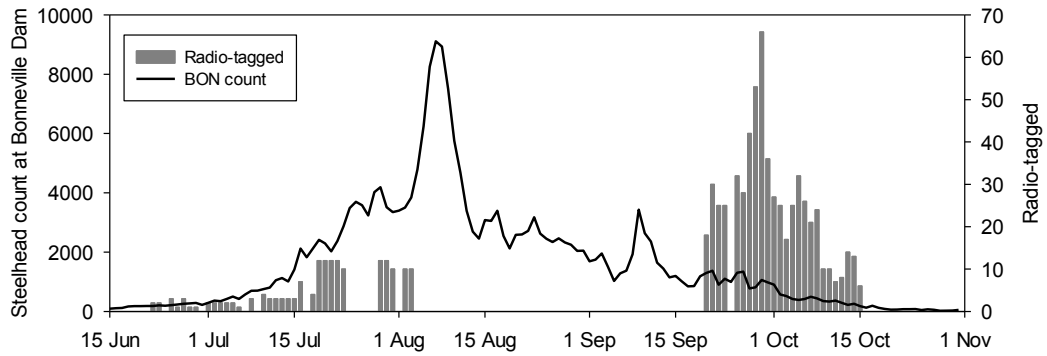


Figure 1. The numbers of adult steelhead (total $n = 789$) that were radio-tagged and released downstream from Bonneville Dam in relation to the daily count of steelhead at the dam in 2013. Sampling targeted adults returning during the late season and was limited during August and September by temperature restrictions on tagging.

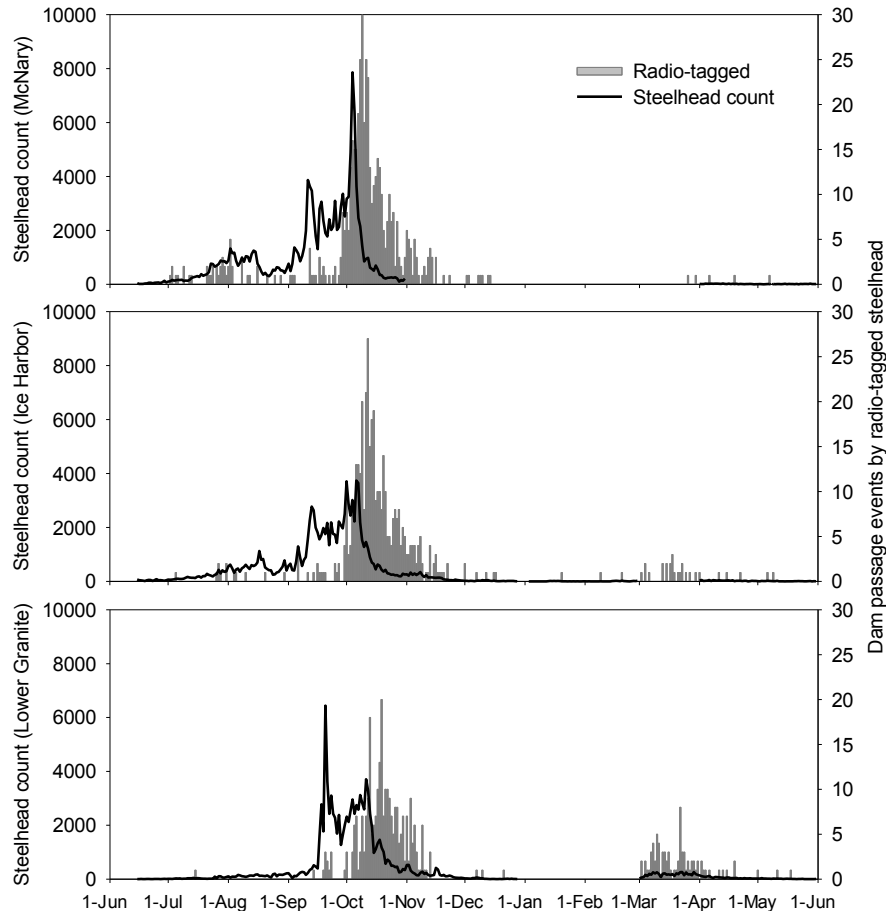


Figure 2. Migration timing of radio-tagged steelhead relative to the run-at-large in 2013-2014. Bars show numbers of radio-tagged steelhead detected on radiotelemetry antennas as they passed McNary, Ice Harbor, and Lower Granite dams and lines show steelhead counts at the dams. Some radio-tagged fish were not detected passing, including ~8% at McNary Dam, 4% at Ice Harbor Dam, and 14% at Lower Granite Dam, mostly due to antenna outages or lost transmitters. These fish are not shown.

Table 2. Last pre-spawn detection sites for steelhead radio-tagged at Bonneville Dam in 2013. Sites determined from radiotelemetry antennas, PIT antennas at dams and in tributaries, and self-reported transmitter returns from fisheries, hatcheries and traps. Post-spawn kelt detections were excluded from this summary.

Last detection site	<i>n</i>	%	Last detection site	<i>n</i>	%
Columbia River main stem	204	25.9%	Snake River main stem	78	9.9%
Downstream Bonneville	¹ 13	1.6%	Ice Harbor Dam	15	1.9%
Bonneville Dam	41	5.2%	Ice Harbor pool	7	0.9%
Bonneville pool	66	8.4%	L. Monumental Dam	6	0.8%
The Dalles Dam	19	2.4%	L. Monumental pool	2	0.3%
The Dalles pool	6	0.8%	L. Goose Dam	14	1.8%
John Day Dam	18	2.3%	L. Goose pool	2	0.3%
John Day pool	5	0.6%	L. Granite Dam	27	3.4%
McNary Dam	19	2.4%	L. Granite pool	5	0.6%
McNary pool	9	1.1%			
Priest Rapids Dam	1	0.1%			
Rocky Reach Dam	1	0.1%			
Wells Dam	6	0.8%			
Columbia River tributaries	123	15.6%	Snake River tributaries	384	48.7%
Little White Salmon River	5	0.6%	Lyons Ferry	1	0.1%
White Salmon River	1	0.1%	Tucannon River	5	0.6%
Hood River	1	0.1%	Clearwater River	233	29.5%
Klickitat River	9	1.1%	Snake > LGR pool	58	7.4%
Deschutes River	33	4.2%	Grande Ronde River	13	1.6%
John Day River	41	5.2%	Salmon River	69	8.7%
Rock Creek	3	0.4%	Imnaha River	5	0.6%
Umatilla River	4	0.5%			
Walla Walla River	5	0.6%			
Yakima River	4	0.5%			
Priest Rapids Hatchery	1	0.1%			
Wenatchee River	6	0.8%			
Entiat River	3	0.4%			
Methow River	4	0.5%			
Okanogan River	3	0.4%			

¹ 12 near release site, 1 in Willamette River

Table 5. Numbers of steelhead released and that met the 1 January criteria for overwintering, and the estimated overwintering percentages for the full sample and the ‘early’ and ‘late’ release groups.

Release group	All released fish included			Harvested, unaccounted fish excluded		
	<i>n</i>	Overwinter	%	<i>n</i>	Overwinter	%
All fish ¹	789	183	23.2%	511	168	32.9%
Early group	169	13	7.7%	98	12	12.2%
Late group	620	170	27.4%	413	156	37.8%

¹ non-representative sample: skewed toward late-run steelhead

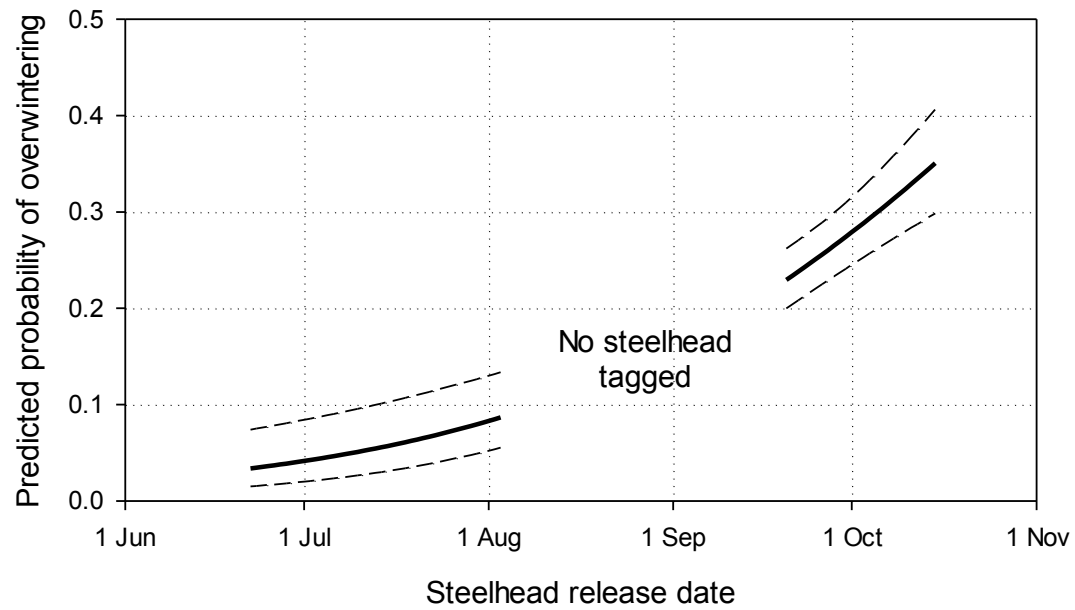


Figure 3. Predicted probabilities (and 95% confidence intervals) that radio-tagged steelhead would overwinter in the FCRPS in relation to release date at Bonneville Dam. Probabilities were generated using a logistic regression model with all tagged steelhead included.

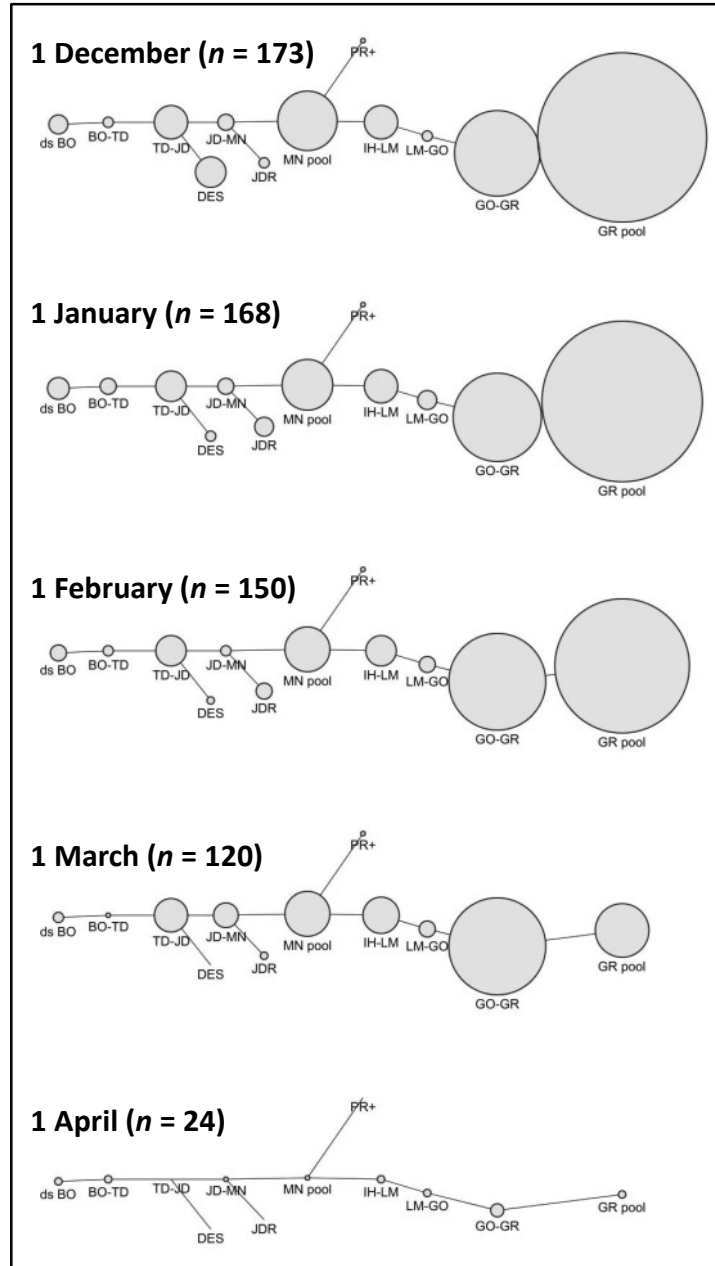


Figure 4. Estimated locations where overwintering radio-tagged steelhead were in the FCRPS on the first of each month from December 2013 to April 2014. Fish in the Deschutes and John Day rivers eventually migrated to other tributaries and so were included here. Circle size is scaled relative to abundance. Sample sizes decrease through time as steelhead entered tributaries.

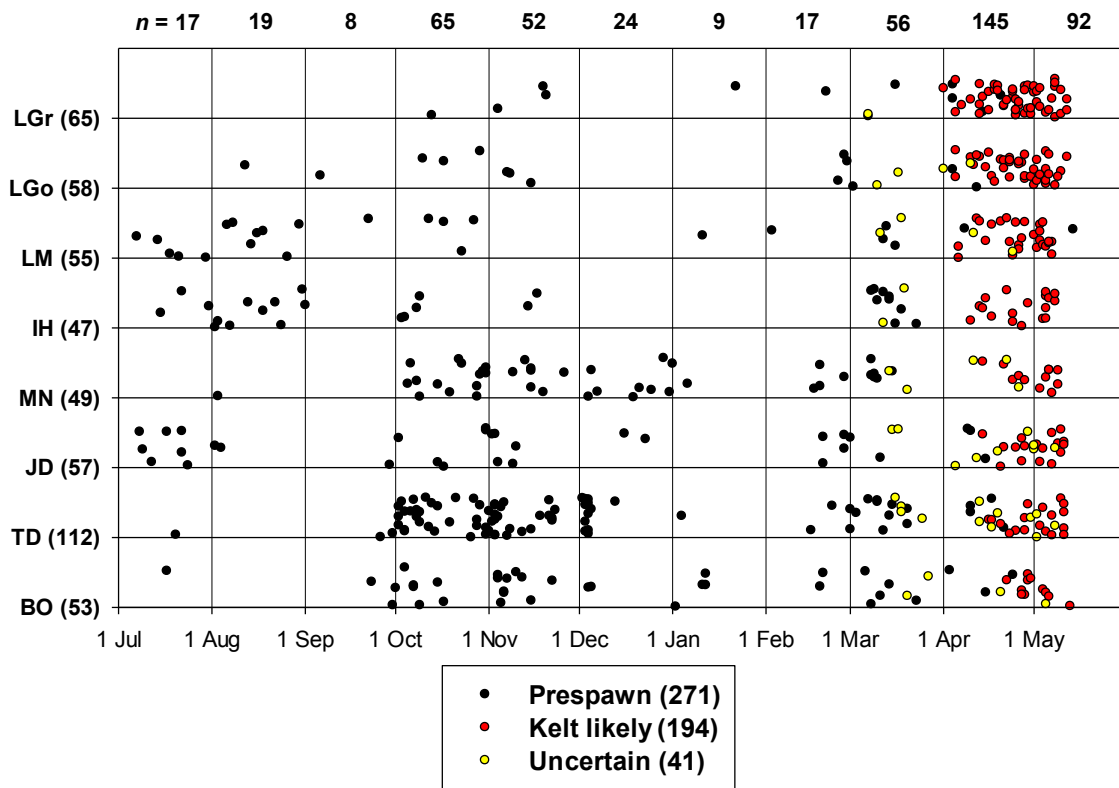


Figure 5. Estimated dates that radio-tagged steelhead fell back at dams in 2013-2014. Fallback events are color coded to represent likely steelhead reproductive status at the time of fallback and randomly jittered on the y-axis for each dam to better display the data. Two fallback events at Priest Rapids Dam and two Bonneville events in June are not shown.

Table 6. Estimated fallback routes of overwintering steelhead at The Dalles, John Day, and McNary dams during forebay radiotelemetry monitoring¹ in 2013-2014. Aerial radiotelemetry coverage in the forebay was not definitive for assigning fallback route, particularly via the spillways, powerhouses, and navigation locks. Underwater or shielded radiotelemetry antennas in the ice and trash sluiceways and fish ladders allowed for a higher confidence “likely” route assignment to these locations. Fish that fell back but had no radiotelemetry forebay detections did not receive a route assignment. No fish in these groups were detected on juvenile bypass (JBS) PIT tag antennas. The % in tributary category summarizes post-fallback fate.

Dam	n	Fallback route (estimated)					% in Tributary
		Possible spillway	Possible powerhouse /navlock	Likely ice / trash ²	Likely ladder	No radio detections	
The Dalles	19	1	9	4	1	4	68%
John Day	10	1	6	-	-	3	50%
McNary	21	7	8	1 ³	2	3	71%

¹ start dates were 11 Dec (The Dalles), 16 Dec (John Day), and 5 Dec (McNary); end dates were 1 April

² McNary ice / trash sluiceway was dewatered for part of the winter study period

³ event recorded on 19 December was possible false positive; dewatering status uncertain

Table 7. Numbers of radio-tagged steelhead that fell back at dams in 2013-2014 prior to spawning (i.e., no known or suspected kelt fallback events included) and the percent that was eventually followed by tributary entry (% Trib).

Dam	22 Jun – 31 Aug		1 Sep – 31 Oct		1 Nov – 31 Mar		All dates [†]	
	<i>n</i>	% Trib	<i>n</i>	% Trib	<i>n</i>	% Trib	<i>n</i>	% Trib
Bonneville	3	33%	9	22%	23	39%	38	39%
The Dalles	1	100%	29	52%	48	50%	82	54%
John Day	9	67%	6	67%	13	46%	31	61%
McNary	1	100%	14	64%	27	70%	42	69%
Ice Harbor	11	55%	5	80%	11	82%	27	70%
L. Monumental	12	33%	5	40%	5	40%	24	38%
Little Goose	1	0%	4	75%	5	40%	13	77%
Lower Granite	1	0%	1	100%	7	71%	13	85%
Any dam	38	50%	73	55%	141	56%	271	58%

[†] includes some presumed pre-spawn events in April and May 2014

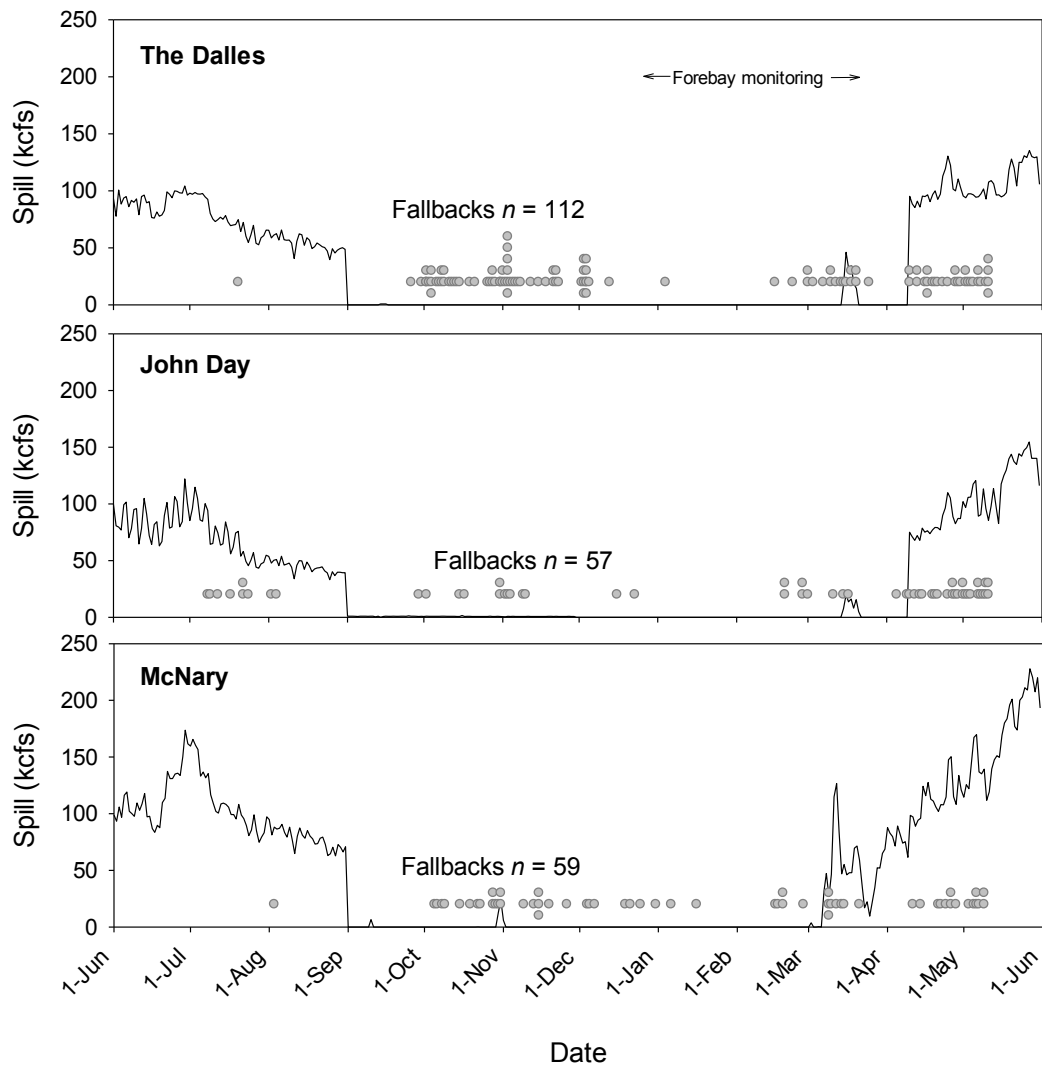


Figure 6. Estimated radio-tagged steelhead fallback dates at The Dalles, John Day, and McNary dams in relation to spill. Dotted vertical lines show dates that additional radio antennas were deployed in the forebays and tailraces to monitor winter fallback and estimate fallback routes (see Tables 1 and 6).

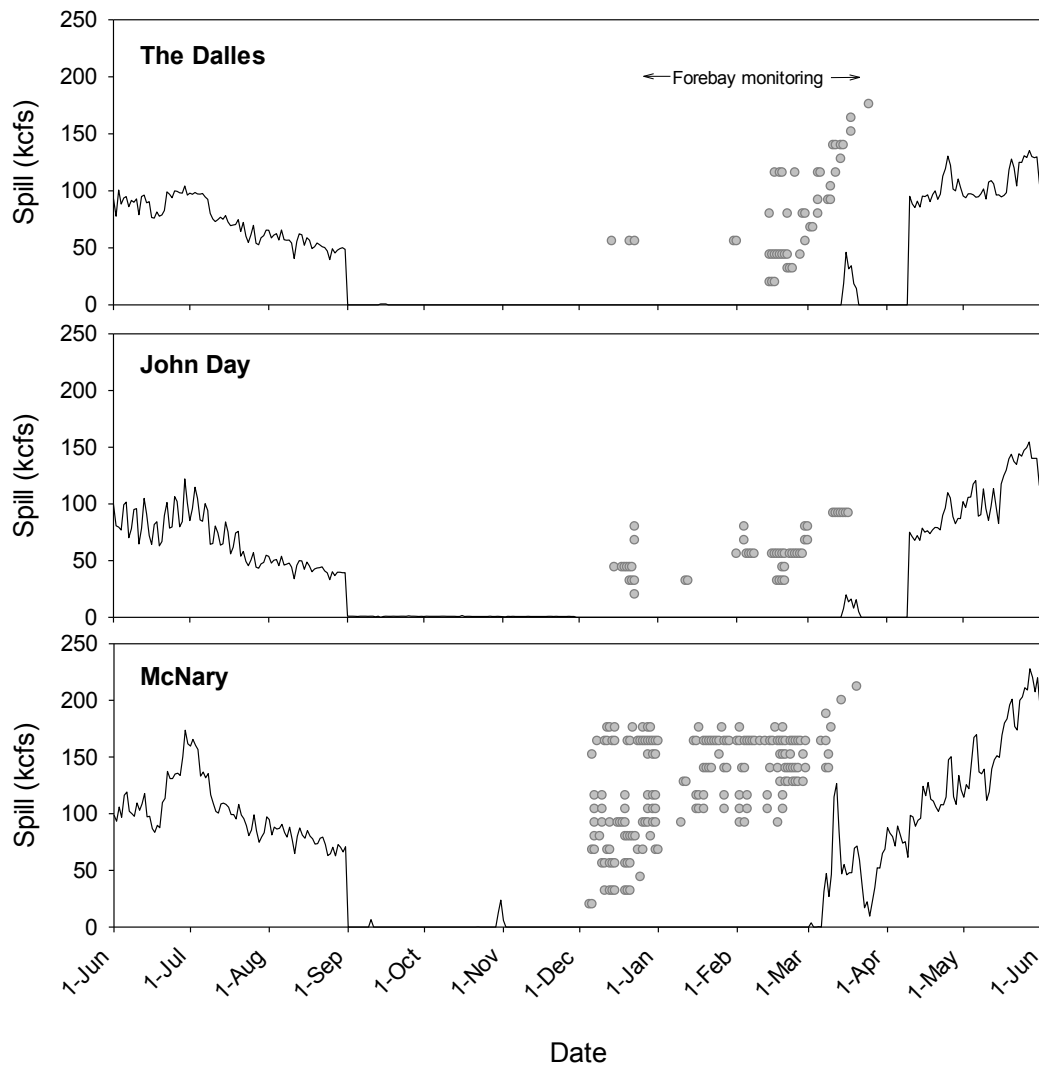


Figure 7. Unique dates that radio-tagged steelhead were detected on antennas used to monitor the forebays of The Dalles, John Day, and McNary dams. Graph only includes steelhead that fell back at the dam during the winter monitoring period. Each row of circles represents an individual steelhead. Note that not all overwintering fish that fell back were detected on forebay antennas.

References

- Brannon, E. L., M. S. Powell, T. P. Quinn, and A. Talbot. 2004. Population structure of Columbia River basin chinook salmon and steelhead trout. *Reviews in Fisheries Science* 12:99-232.
- Colotelo, A. H., B. W. Jones, R. A. Harnish, G. A. McMichael, K. D. Ham, Z. D. Deng, G. M. Squeochs, R. S. Brown, M. A. Weiland, G. R. Ploskey, X. Li, and T. Fu. 2013. Passage distribution and Federal Columbia River Power System survival for steelhead kelts tagged

above and at Lower Granite Dam. Draft Report PNNL-22101 of Battelle to U.S. Army Corps of Engineers.

Keefer, M. L., C. T. Boggs, C. A. Peery, and C. C. Caudill. 2008. Overwintering distribution, behavior, and survival of adult summer steelhead: variability among Columbia River populations. *North American Journal of Fisheries Management* 28:81-96.

Keefer, M. L., and C. C. Caudill. 2014. Homing and straying by anadromous salmonids: a review of mechanisms and rates. *Reviews in Fish Biology and Fisheries* 24:333-368.

Keefer, M. L., C. A. Peery, W. R. Daigle, M. A. Jepson, S. R. Lee, C. T. Boggs, K. R. Tolotti, and B. J. Burke. 2005. Escapement, harvest, and unknown loss of radio-tagged adult salmonids in the Columbia River - Snake River hydrosystem. *Canadian Journal of Fisheries and Aquatic Sciences* 62:930-949.

Khan, F., I. M. Royer, G. E. Johnson, and S. C. Tackley. 2013. Sluiceway operations for adult steelhead downstream passage at The Dalles Dam, Columbia River, USA. *North American Journal of Fisheries Management* 33:1013-1023.

Rayamajhi, B., G. R. Ploskey, C. M. Woodley, M. A. Weiland, D. M. Faber, J. Kim, A. H. Colotelo, Z. Deng, and T. Fu. 2013. Route-specific passage and survival of steelhead kelts at The Dalles and Bonneville dams, 2012. Draft Report PNNL-2246 of Pacific Northwest National Laboratory to U.S. Army Corps of Engineers.

Wertheimer, R. H. 2007. Evaluation of a surface flow bypass system for steelhead kelt passage at Bonneville Dam, Washington. *North American Journal of Fisheries Management* 27:21-29.